THE IMPORTANCE OF WASTE RE-USE

Michael G. McGarry

International Development Research Centre
Box 8500, Ottawa K1G 3H9
Canada

Paper presented to the Symposium on Engineering, Science and Medicine in the Prevention of Tropical Water-Related Disease

11-14 December 1978
London, England

THE IMPORTANCE OF WASTE RE-USE

Michael G. McGarry

International Development Research Centre, Box 8500, Ottawa K1G 3H9, Canada.

Abstract
In several Asian countries human waste is regarded as a resource. Its fertilizer components are valued in agriculture and fish farming. Current practices are described. Several research projects in the Third World are developing processes which have potential for not only cutting treatment costs but also being profitable.

WASTE RE-USE IN AGRICULTURE

Human wastes have often been termed "resources out of place"; in some countries these resources have been valuable and important assets to agricultural development. The East and West have diverged on this point. Whereas excreta was looked upon as an undesirable to be flushed away for later treatment and discharge during the last century of industrial development in the West, in East Asia excreta or nightsoil was collected, treated and applied to the land. In China, it was and is a very important element in its food production capability.

The quantity of wastes man emits depends greatly on climate, health and food intake, but for immediate purposes and in terms of its fertilizer value, one can approximate the per capita yearly nitrogen discharge as 5 kg. Nitrogen is only one of nightsoil's useful components; phosphorous (1½ kg as P_2O_5) and potassium (1 kg as K_2O), micronutrients, and organic matter are also present. On a per capita basis, these quantities may appear small, but on a community basis of 10,000 or more, the quantities of fertilizer are substantial.

In China, nightsoil is applied either directly after partial treatment by storage or in the form of a humus produced by composting mixed livestock manures and crop wastes. The widespread practice of nightsoil and compost application to the soil in China has resulted in its becoming refined to the point that the quantities applied are varied according to the soil type and season, and that the type of manure is matched to the soil and crop being grown (1). The quantities of compost normally vary between 60 and 100 tons/ha; nightsoil applied with moisture contents above 90% are limited to 20-30 tons/ha/application. The advantage of using nightsoil is not only its higher nitrogen content as compared to pig manure and compost but also in the greater availability of its nutrients to crops.

It is estimated that the total net weight of nightsoil collected in China between 1952 and 1966 averaged 244 million metric tons per year (2). This represented a third of all nutrients available to the crops which were applied to the soil during those years. The total quantity of organic fertilizers applied in 1966 was 96 million tons (3). The most recent estimate is that this has increased to current use of 1,545 million tons (1). The relative proportion of nightsoil to other organic fertilizers has fallen due to the upper limit of the availability of nightsoil and the increased production of alternative organic manures.

Data on the effects of nightsoil and manurial compost on soil and crops are scarce. A recent FAO/UNDP study tour on recycling organic wastes in China has provided useful information on Chinese experiments. Benefits have been measured in terms of soil porosity, bulk density, water absorption capacity, enzyme activity and, of course, overall crop yield. In contrast to chemical fertilizers, compost improves the physical characteristics of the soil. By adding humus, the soil becomes more porous and has a greater water retention capacity. This has important implications for soil erosion control. In Szechwan, an experiment showed that in sloping sandy soil the runoff was 16% less in soil treated with compost with 41% less erosion.

The levels of enzymes required to break down protein and urea are also increased by addition of compost; thus proteinase and urease are more available and active which release more nitrogenous materials and, more important, mineralized nitrogen compounds for use by the crops. The liberation of CO_2 and decomposition of organic matter in the soil is likewise accelerated by raised levels of dehydrogenase and hydrogen peroxidase (1).

Field experiments were carried out throughout China to reveal the effect of applying compost to rice fields. The overall indication was that an application of 500 kg of compost resulted in an increase of from 25 to 50 kg of rice grain. The application of compost has a residual beneficial effect on the soil which lasts over the years; again, this contrasts with mineral fertilizers which through continuous use tend to deteriorate most soils. One aspect that has not been well studied is the addition of micronutrients to the soil. However, most of the Chinese soils exhibit no micronutrient deficiencies as a result of long-term use of organic manures. In one experiment, compost was applied to potato, wheat, millet, and sorghum fields at a rate of 38 tons/ha; increases in yields were 89%, 38%, 48%, and 85%, respectively. Of course, these results and those reported above may not be repeatable over a wide range of conditions. They are merely presented as an indication of the benefits through use of manurial compost. One point that should be emphasized is that China is using an ever-increasing amount of mineral fertilizers in response to the more recently adopted practice of double and triple cropping. Organic fertilizers are limited in quantity yet they still represent some two thirds of the total nutrient intake and heavy reliance on these manures will continue in the future.

The direct application of untreated excreta is, of course, to be condemned and was probably the primary cause of the very high levels of helminthic disease in China during the first half of this century (4). In view of the recognized value of nightsoil to the farmers, its use in agriculture could not be banned. Over the past two decades, mass campaigns and public health programmes have introduced practical modifications to existing practices. This began with simple storage beside the fields in enclosed containers which fosters destruction of schistosome and hookworm ova and settlement of other parasites. Naturally, this was not an absolute barrier against disease transmission, but it was an improvement. More complicated but more effective technologies for treating the nightsoil in combination with other organic wastes are now being propagated throughout China. These include the biogas plant and a variety of composting techniques.

Over the past three years, several research projects have been initiated which focus on appropriate technologies for sanitation and include agricultural re-use of the treated waste. These include projects in Tanzania, Botswana, Ghana, Korea, and Zambia. A bibliography on low-cost options for sanitation has recently been published by the International Development Research Centre (IDRC) and the World Bank (5). There is no need at this point to elaborate on the several technologies available; however, a brief listing and description of those already widely used or those with greatest potential would be useful.

<u>Treatment by storage and methane production</u>

<u>The three-stage septic tank</u> is an improvement over the storage pot beside the field. It consists of three tanks operated in series receiving nightsoil and pig manure with little or no dilution (Fig. 1). Its design ensures that the waste undergoes a minimum storage time of 40 days before being applied to the land. It is effective as a means of reducing pathogen content as reported in a recently published manual (6).

<u>The biogas plant</u> has received a great deal of publicity as a means of treating cattle and pig wastes in India, Korea and China. The by-products are digested slurry with improved fertilizer qualities and an energy source in the form of methane gas for cooking and lighting. In the State of Haryana, India, 30% of the biogas digesters are fed nightsoil. Although the practice is not as common in other parts of India or in Korea, it is in China where biogas toilets are attached directly to the digester. Of course, conditions vary considerably, but, as an example, a family of eight owning four cattle, two pigs, and a digester could produce about 3 m^3 of gas daily which would keep three gas lamps operating for five hours and a gas ring cooking for three hours. The effluent slurry can be applied directly to the land or fish ponds; more commonly, it is dried or composted with other organic wastes. Problems have been encountered in India with the capital cost of construction and maintaining the digester's steel gas collector dome. The Chinese use a fixed top digester which overcomes these problems, although great care has to be taken during installation and to ensure that it is leakproof (Fig. 2). Design and operating criteria of the fixed top digester have been translated and are available (6); a more detailed manual of construction will soon be published by the Intermediate Technology Development Group (ITDG).

<u>Composting</u>

There are numerous variations of composting techniques as described by Gotaas (8). Over the past twenty years, the Chinese have introduced simple but important improvements. Their methods of composting with nightsoil fall into two categories: granular (dry) composting and thermophilic composting (the four-combined-in-one method).

<u>Granular composting</u>. Mud is dried, ground and stored in fertilizer sheds (Fig. 3) where it is mixed with nightsoil and/or pig manure in equal proportions or to achieve a maximum

moisture content of 20%. Where ash is used, it is mixed with nightsoil and dried ground mud in 2:3:5 proportions. The mixture is piled for composting. Average temperatures in the pile reach 40°C; above 90% kills of ascarid ova are reported (1).

Thermophilic composting. The four-combined-in-one method achieves higher temperatures (50-60°C) by composting the wastes aerobically. Four waste materials (nightsoil, pig manure, refuse including crop wastes, and soil) are combined in equal proportions by weight and piled in layers. Poles are placed in the compost and a day later removed to provide natural ventilation (Fig. 4). The pile is covered with 2 to 3 cms of mudpack which keep the heat and odours in and flies out. Ascarid ova kills are reported to be 94 to 100% and coliform levels reduced by three orders of magnitude. In colder climates, dug pits with prepared aeration channels and vent stacks through the compost can be used.

Thermophilic composting is also used in urban centres. After non-compostable materials such as glass and metal are removed, urban refuse (70-80% by weight) is mixed with nightsoil and placed in layered piles. Bamboo poles are placed in the pile to provide natural vents and are afterwards withdrawn. A 2- to 3-cm coating of soil ash and water mix is used to seal the pile. Pile temperatures of 50 to 55°C are reached within one to two days and maintained over the following ten days. The compost humus is ready in three to four months (1).

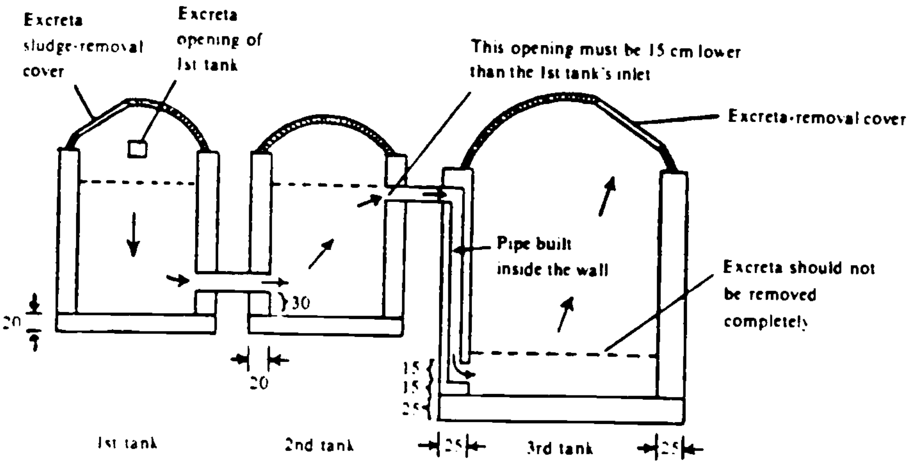

FIG. 1. The three-stage septic tank.

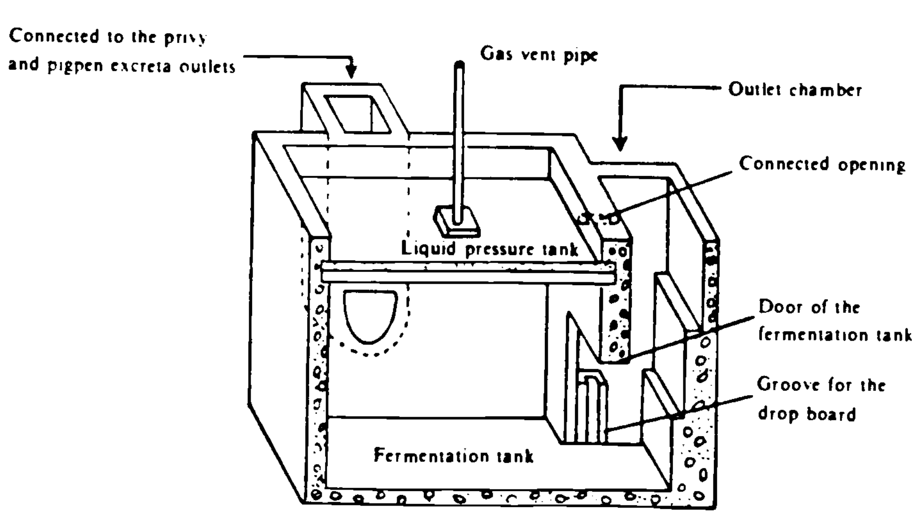

FIG. 2. The fixed top digester.

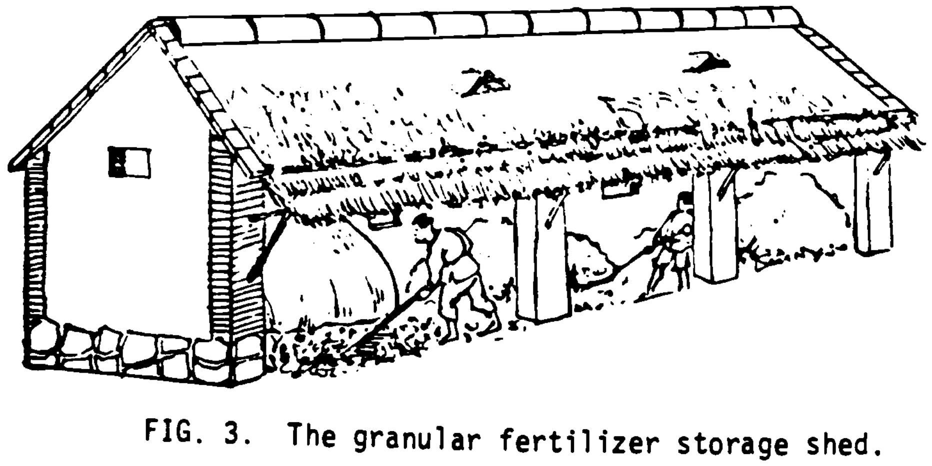

FIG. 3. The granular fertilizer storage shed.

Compost toilets. Research in Tanzania and Botswana has concentrated on individual toilet units. Many configurations of "multrum" type toilets have been tried. In these, the deposited excreta, household refuse, and urine slide slowly down the sloped floor of the vault for later removal as humus material. Neither project could recommend this "continuous" type of compost toilet. They were found to be difficult to operate properly at the village level, excess moisture tended to gather in the humus collector vault and there was always a danger that pathogens would "short-circuit" the system by being washed down into the humus vault. Where excreta re-use is desired, both projects favoured the alternating double vault principle (9 & 10) but had reservations as to its sensitivity to misuse and the acceptability of the re-use concept on an individual basis.

The double vault concept is widely used in Vietnam. Urine is separated from the faecal material (Fig. 5), the latter is deposited into one of the vaults and ash poured on top after defecation to reduce odours and improve the compost process and subsequent fertilizer value of the humus. When the first vault is full, it is covered with ash and soil and sealed off while the second vault is put into operation. After two months, the digested waste material, which is by then a humus, is removed from the back of the vault. Vietnamese studies on hookworm ova in the double vault unit indicated an 85% kill within eight weeks. Increased crop yields by using double vault humus are reported over those using untreated nightsoil (13).

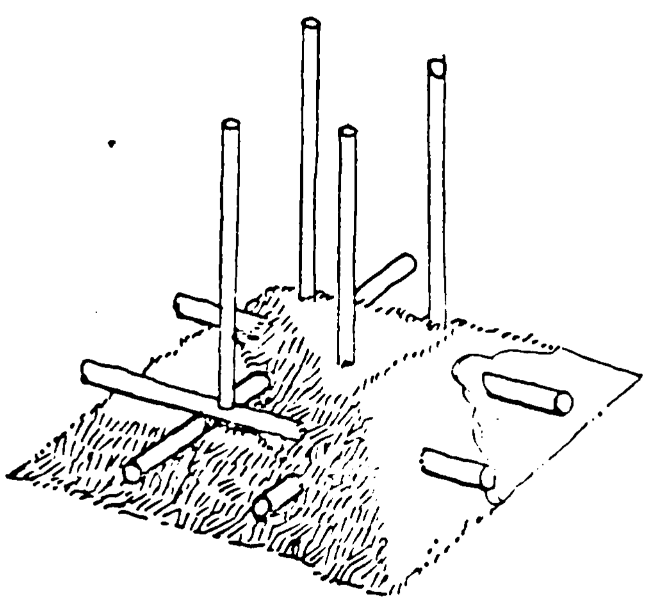

FIG. 4. The thermophilic or four-combined-in-one method of aerobic composting.

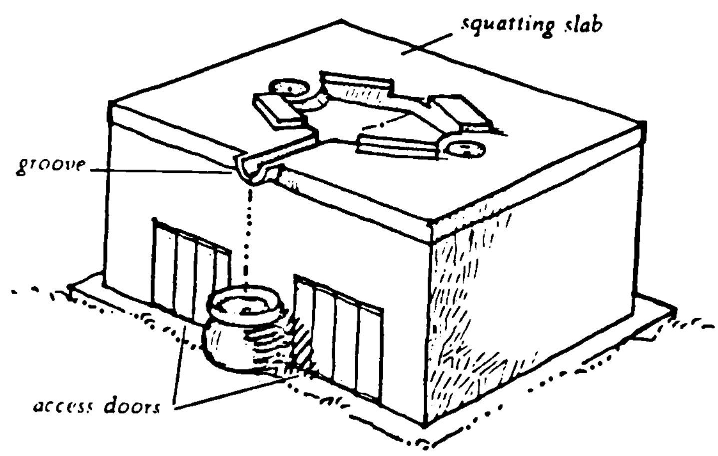

FIG. 5. The Vietnamese double vault toilet without superstructure.

WASTE RE-USE IN FISHERIES

There are about 6,000 hectares of fish pond surrounding the city of Tainan in Taiwan. Nightsoil collected from the city is introduced to the ponds and is used either directly or indirectly as fish feed. The nightsoil is sold by the municipality to the fish farmers; it has an economic value. During peak demand season, it is stolen from the household vaults very early in the morning and sold at a higher than official price; there is in effect a black market in nightsoil. Use of human excreta in fish farms has been a traditional practice in China for many decades. Now, however, the waste is subjected to a two- or three-week anaerobic storage before being introduced to the ponds. Fish farms combine livestock production with fish culture. Pig and human wastes are an important source of nutrients, including micronutrients. For example, a piggery of 30 to 45 pigs will supply adequate manure for one hectare of carp pond (15). Other wastes such as crop stalks and refuse are also composted before being introduced to the pond as an organic fertilizer.

In the suburbs of Calcutta, sewage is fed into ponds which produce algae and, subsequently, fish (Indian carps and *Tilapia*). There are several thousands of hectares of these ponds producing fish for the Calcutta markets. The fish grow to marketable size within five to six months when the population is thinned out. Data on fish yields are not readily available, but some farmers report yields as high as 15 to 20 tons/ha/year although the average yields are considerably less. Fish yields are normally in the order of between one and two tons. They sell for about 4 to 6 rupees per kilogram (1974). The wastewater is essentially free and the fish farm profitable.

Fish can be used to improve the oxidation pond's treatment capacity. Phytoplankton (algae) is a major food chain component between wastewater nutrients and the product fish. By introducing fish, one extends the natural food chain beyond zooplankton normally found in waste pond systems. High alkalinities, pH's and calcium are common in fish ponds and these assist in phosphate removal. Similarly, nitrogen is bound up in the fish itself which is later harvested; the relatively high pH's encourage volatilization of the ammonia which is released as a gas. High pH's and dissolved oxygen levels have been claimed to increase the rate of disinfection as indicated by coliform die-off rates (17). Apart from these benefits, there is the fish product which can be measured in monetary terms.

Conventional fish farming requires supplemental feed such as seedcakes, rice and wheat bran and vegetable wastes. Such feeds often account for over fifty percent of the cost of production. Wastewater-fed ponds produce higher yields than supplementally fed ponds because of the increase in natural fish feed (phyto- and zooplankton) produced from the wastes. Hepher and Schroeder (18) demonstrated a 70% increase in fish yield with a 40% decrease in supplemental feed required to grow a unit weight of fish. Yields of 3,500 kg/ha were achieved over an eight-month growth period. In Madras, carp ponds were fed oxidation pond effluents. Fish maturity was achieved in six months. The ponds produced an estimated 7,700 kg/ha/year of fish (19).

A network of research projects has been established to look into the treatment, yields, and public health aspects of fish production in sewage ponds in five countries: Kenya, Israel, Malaysia, Peru, and Thailand. It is too early to draw definite conclusions from these projects; however, some indications can be reported. In Israel, common and silver carps are being studied in polyculture with *Tilapia*. Their ponds are being fed raw sewage and compared with those receiving high-rate algal pond effluents. Although one cannot yet report on productivity, some trends in pathogenicity and bioconcentration of pesticides are apparent. There were increases in coliforms in the various organs of the fish grown in the sewage-fed ponds. As expected, these were concentrated in the digestive tract. No *E. coli* phages were recovered from any other organ. No *salmonella* were detected after one month in the sewage-fed pond. It is emphasized that the relatively few observations taken to date are not conclusive although a trend is apparent in which the bacterial concentrations in the fish increase with exposure to the pond waters. The beneficial "clean-out" effect of keeping the fish in a clean water depuration pond (as practiced in effluent-fed fish ponds of Germany and Indonesia) has yet to be tested (20).

In Thailand, high-rate algae ponds are being used to treat sewage and produce algae before being fed into *Tilapia* culture ponds. To date, *Tilapia* has been stocked at 1, 10, 20, and 30 fingerlings/m^2 in ponds of 2, 3, 10, and 40 days detention. It is dangerous to extrapolate yields from small ponds to prototype scale conditions. However, the results indicate that yields approaching 20 tons/ha-year may be attainable (21). This compared favourably with previous work carried out on high-rate algal pond-fed *Tilapia* by McGarry and Durrani (22). Even higher yields at sewage-fed farms near Calcutta are reported where a growing period of 2-3 months in ponds totalling 2.5 hectares at 7 fingerlings per hectare yielded 28 tons/ha-year. Tapiador (23) suggests that if the fish were grown in several crops per year up to about 30 g/fish, it is conceivable that a production of 50 tons/ha/year could be attained. Edwards points out that carnivores such as catfish and prawns are highly priced on the market. By growing *Tilapia* at the size associated with maximum productivity, and harvesting and feeding them to carnivores, one could increase overall profitability of the system and introduce a further barrier to disease transmission by the pond-fish-man route. It may also alleviate problems associated with non-acceptance of fish grown on waste material. Polprasert and Edwards are now proposing to carry out studies on this sytem which will include feeding septic tank sludge directly to *Tilapia* ponds at the Asian Institute of Technology in Bangkok. Additional steps to reduce the potential of disease transmission could be sterilization of the *Tilapia* intermediate product or its cleansing in depuration ponds.

Should optimization of the waste treatment fish culture system be approached in the conventional engineering fashion and, therefore, the ponds' area minimized? Alternatively, should it be looked on as a fish production unit according to the fish farmers' point of view? This latter viewpoint would mean maximizing yield per food (waste nutrients) input and thereby result in far larger pond areas than the conventional sewage ponds would require. The answer will be site-specific and require economic and financial analyses after adequate data on treatment, yields, costs, etc., are generated. At this stage, it is possible to foresee that the treatment/production process will be profitable and that in producing fish one can expect to meet treatment objectives normally attained by conventional oxidation pond treatment. The major variables to which the system is most sensitive are: (1) the availability and costs of the wastes, (2) productivity of the fish under culture, (3) their market price, (4) cost of land, and (5) capital costs of construction. The most profitable design in a given situation would vary between a conventional fish farm using nightsoil as its nutrient source (100 persons/ha) and conventional stabilization ponds in which fish are cultured as a by-product. The latter situation could be dictated by high land (opportunity) costs close to a larger metropolitan area. Even at lower loading rates, the fish are unable to consume all the algae and large amounts escape with the effluent. This argues in favour of the effluent itself being used to irrigate crops (19).

Small-scale backyard ponds are used for fish production at the family level in many Asian countries. In the Southeast Asian region, they are most developed in Indonesia — especially in Java where toilets can be seen perched over the ponds. President Suharto has recently advocated the expansion of the use of these waste-fed ponds in Indonesia as part of a nationwide campaign to increase fisheries production and the availability of protein in the rural areas. In other countries, this practice is given less recognition, but it is apparent from the few data that are available that backyard nightsoil-fed ponds do provide an important source of food and a technically viable method of waste re-use at the village level.

Little is known of the transfer of pathogens through the pond and fish cooking processes, but it is an age-old custom to use clean water depuration ponds to flush out the digestive tract and clean the exterior surfaces of the fish. In both Indonesia and China, re-use of excreta is extended to a further degree — the faeces of the fish are themselves collected from the bottom of the pond to fertilize nearby crops. The pond bottoms are rich in humus and fertilizer. The pond is emptied four or five times a year and the pond muds pumped to fertilize vegetable gardens, banana plantations, and even sugarcane fields. It is reported that 85 kg of fish produce enough pond mud to fertilize a hectare of land (1). This represents a highly developed form of nitrogen recycling from plant to man, to algae, to fish, and back to plants. The University of Malaya and the IDRC have recently initiated a collaborative research project with local institutions in Indonesia, Bangladesh, Taiwan, Malaysia, and India which will investigate existing practices and survey their extent and importance.

DIRECT ALGAL HARVESTING

In aquaculture, fish such as *Tilapia* are used to harvest the algae from the ponds. A more direct method would be to remove, dewater, and dry the algae before using it as feed for livestock. The direct harvesting approach has potential not only from the viewpoint of its being a chemical or mechanical harvesting process and, therefore, controllable, but also in terms of its very high production rates of algae (approaching 100 tons/ha/year, dry weight basis) which are 50% protein. These production rates are attainable in ponds which are especially designed to optimize algal growth conditions. These high-rate algae ponds are normally 2 to 4 days in detention and 30-50 cm in depth, designed in a racecourse configuration and are frequently mixed. The concept of mass algal production and direct algal harvesting has attracted researchers over the past two decades during which pilot projects have been carried out in California, Australia, Germany, Thailand, Israel, and now in Singapore and the Philippines.

Sixty percent of Singapore Island has been designated as a protected catchment area to conserve Singapore's already scarce water supply. This has necessitated the relocation of the majority of its pig farms (750,000 pigs) into one area. Last year, research began on a high-rate algae pond system (24) which treats the wastes after removal of the settleable solids by conventional sedimentation. To date, the ponds being studied have been scaled up from the original 5 m^2 ponds through 10 m^2 mini pond size to four pilot ponds each 125 m^2 in area. Two demonstration ponds of 1,240 m^2 each are under construction and a full-scale 6-ha pond system is planned for construction following harvesting experiments. Unlike previous studies on human wastes, the dominant genus is *Micractinium* which is conducive to mechanical harvesting. The alternative harvesting process is alum flocculation by flotation with subsequent removal and re-use of the aluminum before the algae is either fed back directly to the pigs or is dried and stored for later use. For purposes of estimating the value of the algae, preliminary feeding trials were conducted on pigs. The soybean was removed from their regular diet and replaced on a dry weight basis with the algae. In terms of daily weight gain, feed conversion ratio, blood uric acids, taste and colour, there were no significant differences between the control pigs on the regular diet and those fed algae. This provides tentative evidence that algae can be valued at the soybean price of U.S. $250-350/ton. There is evidence that algae can be used to replace fish meal in livestock diets; if so, the value of algae might be equivalent to that of fish meal (U.S. $400-450/ton). At the full plant scale, it is intended to feed the algae directly back to the pigs as protein supplement. The clarified water will also be recycled back to the piggery as wash water. Thus, by minimizing the quantity of blow-down, a minimum demand for water will be exerted on Singapore's limited supplies.

This project has important implications for research into human wastes treatment and production of algae for livestock feed. These will be in terms of algal growth parameters, including scale-up factors, engineering design, and harvesting technologies. The Laguna Lake Development Authority has been carrying out research on treatment of sewage from the University of the Philippines (Diliman Campus) by high-rate algal ponds (25). A technique of harvesting by autoflocculation or settling the algae under nutrient-limited conditions has been developed which is reported to remove between 70 and 90% of the algae from the effluent. This approach could considerably reduce the costs of algal harvesting. Further tests are required including increasing the size of the ponds and the development of engineering and operational criteria for the full-scale plant. This method of harvesting, backed by mechanical or chemical harvesting during periods when autoflocculation is inefficient, is the most promising in terms of cost reduction. As the alternative costs of feed and water continue to rise, the high-rate algae pond will become an economically feasible, if not profitable, method of waste reclamation. It holds significant potential for tipping the balance in favour of sewage and excreta becoming looked upon as an economic resource rather than as an unwanted pollutant.

PUTTING RE-USE INTO PRACTICE

Many questions remain unanswered within this subject area of waste re-use. In particular, inadequate data have been generated on the transmission of disease through the various processes — including the longevity of pathogens through market, washing, and cooking practices. Similarly, the economics of the various techniques are site-specific and have not been adequately studied. A significant amount of this information will be available within the coming two years as many of the research projects generating it are now well under way. What are the best means for propagating these processes within the developing countries for the benefit of the lower income groups?

Information dissemination

Most international conferences on the topic of water supply and sanitation for the Third World are organized by institutions within the industrialized countries and held in those countries. There are very few relevant journals published within the developing countries. The developing-country researcher is faced with having to present and publish his results in an industrialized country. This has tended to distort the orientation of the available literature; indeed, it often influences the researcher to such a degree that his work is focused not on his own country's critical problems but on those of the industrialized state. An example of the information dissemination problem was illustrated in the preparation of the bibliography on Low-Cost Technology Options for Sanitation (5). Keyword retrieval of documents from 15 American and European information retrieval systems produced over 20,000 publications. However, this vast number contained only 188 items which were relevant and abstracted for the bibliography. "It is not surprising that the data bases are, after all, enterprises that reflect the information requirements of their clientele, which are universities, engineering firms, and government agencies in North America and Europe. As a result, more than 99% of the published literature on wastewater is of no practical value to the urban and rural poor in the developing countries." (15) The vast majority of relevant publications came from reports and articles which are not available to international readers. These had to be identified by searching through selected personal holdings and institutional libraries throughout the world. Fortunately, the Asian Institute of Technology has established an Environmental Sanitation Information Centre which, being based on the bibliography, will disseminate its abstracted articles in microfiche or hard copy upon request. It will also issue a quarterly newsletter, establish a journal, and regularly update the bibliography itself. This is a first step in overcoming an outstanding bottleneck in this field.

Problems of technology transfer

Putting the various technologies into practice runs into two fundamental problems. The first pertains to the difficulties of transferring concepts between developing countries. Although some of the technologies have been practiced in China for decades, most require some form of investigation for their development or to establish their viability in the country of intended use. It has been possible within large corporations enjoying a research and development capability to bring some technologies from invention through the necessary stages of research, development, dissemination, and demonstration to general practice within a time span of from five to ten years. In this case, the problem is one of research and development in diverse countries which have very limited capacity; dissemination through extremely limited channels of communication; demonstration in the public sector by rather skeptical and reluctant municipal authorities and putting into general practice by public bodies handicapped by lack of financial and manpower resources.

The second basic problem deals with the nature of the sanitary engineer himself. Traditionally, medicine and civil engineering have been two of the most conservative professions. The sanitary engineer, with feet in both camps, has acquired their conservative characteristics and appears insulated from other related fields such as economics, aquaculture, and agriculture. The sanitary engineer has always designed on the basis of minimizing costs and meeting standards. This is in contrast with designing to maximizing profits while ensuring environmental quality improvement. The problems of applying new concepts in developing countries have been compounded by the fact that most of the designs have come through consulting engineering firms based in the industrialized countries. Commonly, these consultants have neither the necessary experience with, nor the confidence in, low-cost appropriate technologies. Consequently, they tend not to suggest them as viable alternatives to the more conventional capital-intensive schemes.

Lack of familiarity with local conditions and a dearth of basic field data frequently result in overdesign. Sanitary engineering as a profession is not well established in Asia and Africa. This, coupled with reluctance of international consultants to design for alternatives, tend to make the developing-country engineer reticent to consider the alternatives. An example is given as the case of the slow transfer of oxidation pond technology in Asia. Although they were being accepted and constructed for the cold climate of Alberta, Canada, in the 1940's, it wasn't until the seventies that Malaysia began to resist suggestions to purchase activated sludge plants and install pond systems.

It is the sanitary engineer's assumed premise that disease may be attacked by limiting the number and virulence of pathogens reaching man. Unfortunately, it is almost invariably limited to just that. In many countries, mortality amongst children under five years accounts for more than half of all deaths, the primary causes of which are diseases spread by faeces, airborne infections and undernutrition, all of which are reinforced by poverty. These three types of malady account for between 70 and 90% of childhood deaths in the Third World today (26). Although drought and starvation attract international publicity, and rightly so, it is the background condition of undernutrition combined with infection which largely accounts for the high mortality in this young age group.

The small child requires about twice as much protein and calories per kilogram of body weight than his parents do. In a situation such as Indonesia, where the national caloric intake average is between 1,283 and 1,974 calories/capita/day, and protein between 27 and 42 grams/capita/day,* the young child is frequently undernourished (27). Reducing the number of pathogens in the environment will have little effect until his resistance to disease, which is presently undermined by malnutrition, can be raised.

Within the poverty-stricken, disease can only be combatted through a combined approach which both improves environmental quality and makes food more available, especially to the young. The treatment and re-use of excreta has a great deal to offer in this respect, as has been reported in China (1) and Vietnam (13). The household's vegetable garden can be an important source of green-leafed vegetables, legumes such as soybean, and root crops. In particular, the backyard garden can produce essential vitamins and minerals which are not available in common cereal grains. One of the main constraints to this form of horticulture is the lack of fertilizers available to the household. Wastes re-use after treatment by composting is within the control of the family, wastes which are normally discarded and can be used at the village level to improve both nutrition and health. This implies an integrated approach must be taken somewhat along the lines of the integrated rural development projects now being encouraged by the various international agencies. Thus, the resources of the Ministries of Agriculture, their agricultural extension officers in the field, will have to combine with those of the Health Ministries, their clinics and health workers.

The Water Supply and Sanitation Decade of 1980-90 will likely provide some incentive to experiment with low-cost alternatives including re-use systems. Certainly, the international assistance organizations such as the international banks as well as the U.N. and bilateral agencies can play a leading role in this respect. This would best come in the form of carefully designed and carried out demonstration projects at the community level such as the World Bank and UNDP are currently planning. These should be closely monitored to provide feedback information for adaptation and improvement before the approaches are implemented in full-scale projects. Once concrete examples are established and recognized, the task of convincing local authorities of the benefits of re-use should be much easier. Thus, in the future wastes management may well become looked upon as a profit-making venture instead of a subsidized burden on the community.

Neighbouring Australian averages are 3,264 cal/cap/day and 100 gm/day, respectively.

REFERENCES

1. Food and Agriculture Organization of the United Nations, "China: Recycling of Organic Wastes in Agriculture," report on an FAO/UNDP study tour to the People's Republic of China, 28 April - 24 May 1977, FAO Soils Bulletin, No. 40 (1978).

2. M. G. McGarry, "The Taboo Resource....the use of human excreta in Chinese agriculture," The Ecologist, 6 (4), 150-154 (1976).

3. Kang Chao, Agricultural Production in Communist China (1949-1965), Univ. of Wisconsin Press (1970).

4. E. C. Faust, "Some Facts Regarding the Relation Between Nightsoil Disposal in China and the Propagation of Helminthic Diseases," American Journal of Tropical Medicine, 4, 487-505 (1924).

5. W. Rybczynski, C. Polprasert and M. G. McGarry, Low-Cost Technology Options for Sanitation, IDRC-102e, Ottawa (1978).

6. M. G. McGarry, J. Stainforth and T. L. Lee (ed.), Compost, Fertilizer and Biogas Production from Human and Farm Wastes in the People's Republic of China, IDRC Technical Series No. 8e, Ottawa (1978).

7. A. Barnett, L. Pyle and S. K. Subramanian, Biogas Technology in the Third World, IDRC-103e, Ottawa (1978).

8. H. B. Gotaas, Composting, Sanitary Disposal and Reclamation of Organic Wastes, WHO Monograph No. 31, Geneva (1956).

9. W. Kilama, E. K. Simbeye and U. Winblad, Alternative Wastes Disposal Methods, Tanzania 1975-77, Final Report, Tanzania National Scientific Research Council, Dar-es-Salaam (1978).

10. M. D. Blackmore, Low-Cost Sanitation Research Project, Final Report, Ministry of Local Government and Lands, Republic of Botswana (1978).

11. J. K. McMichael, Health in the Third World....Studies from Vietnam, Spokesman Books, U.K. (1976).

12. U. Winblad, W. Kilama and K. Torstensson, Sanitation Without Water, ISBN 91-7260-187-6, Stockholm (1978).

13. Department of Hygiene and Epidemiology, Ministry of Health, Democratic Republic of Vietnam, Double Septic Bins, a booklet published by the Department (1968).

14. M. G. McGarry, "Sewage as a natural resource....economic disposal of domestic wastewaters," proceedings of a Symposium on the Role of the Engineer in Environmental Health Pollution Control, Malaysia, March 1972.

15. D. D. Tapiador, H. F. Hendersen, M.N. Delmendo and H. Tsutsui, "Freshwater Fisheries in China," FAO Fisheries Technical Paper No. 168, Rome (1977).

16. V. G. Jhingran, "A critical appraisal of the water pollution problem in India in relation to aquaculture," proceedings of FAO Indo-Pacific Fisheries Council, New Zealand, 15th Session, Sec. II, 45-50 (1974).

17. W. J. Oswald, "Complete Waste Treatment in Ponds" in Water Quality Management and Pollution Control Problems, Progress in Water Technology, 3, 156-163, Pergamon Press, New York (1973).

18. B. Hepher and G. L. Schroeder, "Wastewater utilization in integrated aquaculture and agriculture systems," Environ. Protect. Tech. Serv. Report EPA-660/2-74-041, 9-15 (1975).

19. S. Muthuswany, S. Govinda and B. B. Sundaresan, "Productivity of *Cyprinus carpio* in stabilization pond effluents," Indian Journal of Environmental Health, 16 (4), 370-379 (1974).

20. B. Hepher, N. Buras, G. L. Schroeder and A. Perry, First Annual Progress Report on Treatment of Wastewater in Sewage Stabilization Ponds with Concurrent Production of Fish, Hof Hacarmel, Israel, submitted to IDRC August 1978.

21. P. Edwards, Second Progress Report on Fish Cultivation in Sewage Oxidation Pond Effluent, Bangkok, Thailand, submitted to IDRC October 1978.

22. M. G. McGarry and S. M. A. Durrani, Reuse of human wastes in agriculture, proceedings of the 11th Session of the National Conference on Agricultural Sciences, Bangkok, Thailand, February 1972.

23. D. D. Tapiador, "A preliminary review on the possibility of commercial fish meal production from sewage fish farming," proceedings of the FAO Technical Conference on Fishery Products, Tokyo, December 1973.

24. B. Y. Lee, First Progress Report on Pig Wastewater Purification, Reclamation and Nutrient Recovery by the High-Rate Algae Pond System, submitted to the IDRC by the Primary Production Department, Ministry of National Development, Singapore, August 1978.

25. W. J. Oswald, E. W. Lee, B. Adan and H. K. Yao, "New Wastewater Treatment Method yields a harvest of saleable algae," WHO Chronicle, 32, 348-350 (1978).

26. E. P. Eckholm, The Picture of Health, Environmental Sources of Disease, Norton Co. Publ., New York (1977).

27. O. Soemarwoto, "Nitrogen in Tropical Agriculture: Indonesia, A Case Study," Ambio, 6, 162-165 (1977).